Zooming for Precise Waveform Measurements

Several traces can be zoomed from a single waveform to obtain precise timing measurements.

For instance, on a waveform composed of two pulses separated by a long delay, Trace A could be made a zoom of the first pulse, and Trace B a zoom of the second.

The combination of long memory and zooming allows extremely accurate time interval measurements. And the time resolution on the viewed trace can be significantly improved.

For example, choosing 50 000 points per channel on a timebase of 0.1 ms/div, traces can be expanded to as much as 50 ns/div — a factor of 2000. Using Relative Time cursors (*see Chapter 14*), a delay of, say, 500 µs could be measured with resolution as high as 0.5 ns. Even with as many as eight million points acquired, zooming can be done until there are only a few points on the screen.

Using Multi-Zoom

With Multi-Zoom, the zoomed region of the waveform can be moved simultaneously along two or more different traces, or two or more regions of the same trace.

When "Multi-Zoom" "**On**" is selected from the "ZOOM – MATH" menu (*see page 10–6*), the horizontal zoom and position controls apply simultaneously to all displayed traces — A, B, C and D — allowing similar sections of different traces to be viewed at the same time. The vertical controls still act individually on the traces: switching from one trace to another is done using the TRACE ON/OFF buttons. The highlighting of trace titles in the Displayed Trace label indicates an active Multi-Zoom.

Zooming Math Functions

When Trace A, B, C or D is defined as a mathematical function rather than as a simple zoom (*see next section*), the zoom controls remain operative and defining another trace as a zoom of the math function becomes unnecessary. In order to view the entire mathematical function, simply cancel any expansion or position change by pressing RESET.

Math Functions and Options

Coverage of the Setup menus for configuring zoom, math and waveform processing functions starts page 10–6. Averaging and Extrema are outlined on this and the following pages.
For details on Enhanced Resolution filtering, see Appendix B.
How to Set Up for FFT (Fast Fourier Transform) is explained at the conclusion of this chapter, while a complete description of FFT practice and theory is presented in Appendix C.
Information on each of the Waveform Processing packages on option is to found in Appendix A.

A wide range of standard or optional mathematical and waveform processing functions are available.

The scope's standard waveform mathematics functions consist of waveform negation, identity, addition, subtraction, multiplication and division, summed averaging of up to 1000 waveforms and the (sin x)/x interpolation function.

Advanced waveform processing features, depending on the options installed, include:

- Continuous Averaging (*menus page 10–9*);
- Summed Averaging of up to 1 000 000 waveforms (*menus 10–9*);
- Enhanced Resolution by up to 3 bits with filtering (*menus 10–10*);
- Extrema — envelope of many waveforms (*menus 10–11*);
- Fast Fourier Transform, including FFT averaging (*menus 10–12 and 10–13*);
- Mathematical Functions such as Integral, Derivative, Logarithm, Exponential, Square, and Square Root (*menus 10–14*);
- Parameter Analysis, histogramming, trending and statistical analysis (*menus page 10–15*).

Continuous Averaging

This is the repeated addition, with *unequal* weight, of successive source waveforms. It is particularly useful for reducing noise on signals that drift very slowly in time or amplitude.

However, the statistics of a continuous average tend to be worse than those from a summed average (*see next page*) on the same number of sweeps. This is because the most recently acquired waveform has more weight than all previously acquired ones: the continuous average is dominated by the statistical fluctuations of the most recently acquired.

The weight of 'old' waveforms in the continuous average gradually tends to zero (following an exponential rule) at a rate that decreases as the weight increases.

Summed Averaging

Summed Averaging is the repeated addition, with *equal* weight, of successive source waveform records. If a stable trigger is available, the resulting average has a random noise component lower than that of a single-shot record.

Whenever the maximum number of sweeps is reached, the averaging process stops. An even larger number can be accumulated simply by changing the number in the "SETUP" "for" menu. However, the other parameters must be left unchanged or a new averaging calculation will be started.

The process may be interrupted by changing the trigger mode from NORM to STOP or by turning off the active trace using the respective buttons. Averaging will be resumed when the inverse is done. The accumulated average is reset by pushing the CLEAR SWEEPS button or changing an acquisition parameter such as input gain, offset, coupling, trigger condition, timebase or bandwidth limit. The number of current averaged waveforms of the function or its expansion is shown in the Displayed Trace label.

When summed averaging is selected, the display is updated at a reduced rate — about once every 1.5 s — in order to increase the averaging speed (points and events per second).

Summed averaging can also be done on sequence waveforms to give the average of the segments. And it can be applied to an expansion of a sequence segment, giving the segment's average waveform over many sequence acquisitions.

Extrema Waveforms

These are computed by a repeated comparison of successive source waveform records with the already-accumulated extrema waveform, which consists of a maxima (roof) and a minima (floor) record. Whenever a given data point of the new waveform is greater than the corresponding maximum roof-record value, or less than the corresponding floor value, it replaces it. Thus the maximum and the minimum envelope of all waveform records is accumulated.

Roof and Floor records can be displayed individually or together.

Whenever the selected maximum number of sweeps is reached, the accumulation stops. The same process may be interrupted by changing the trigger mode from Normal to Stopped or by turning off the function trace. Accumulation will continue when these actions are reversed.

The currently accumulated extrema waveform may be reset by either pushing the CLEAR SWEEPS button or by changing an acquisition parameter such as input gain, offset, coupling, trigger condition, or the timebase- or bandwidth-limit. The number of currently accumulated waveforms is displayed in the function's Displayed Trace Label of that of its zoom expansion.

Whenever the maximum number of sweeps is reached, an even larger number can be accumulated simply by changing the number in the "SETUP" "for" menu. However, the other parameters must be left unchanged or the extrema calculation will be restarted.

Using Waveform Mathematics

Waveform mathematics can be applied to any channel or reference memory. And any trace of A, B, C or D can be set up as a math function, allowing several computations to be made in sequence.

For example: Trace A could be set up as the difference between Channels 1 and 2; Trace B defined as the average of A, and Trace C made the integral of B — thus displaying the integral of the averaged difference between Channels 1 and 2.

In order to avoid slowing down the instrument with unwanted computations, a particular mathematical function is only computed when its display is turned on. However, using the same example as above, it would be sufficient to display Trace C alone, as the instrument knows it must compute A and B as intermediate steps to C.

Waveform processing can also take time when many data points are involved. This delay can be cut by limiting the number of data points used in the computation. To do this, the instrument will process the entire waveform by taking every Nth point, where N depends on the timebase and the desired maximum number of points, and the first point taken is always the data value at the left-hand edge of the screen.

Combining Channels

Zoom and math functions on Traces A, B, C, D and Reference Memories M1, M2, M3, M4 use the instrument's system memory, which is dynamically allocated to each trace as required. When more acquisition memory is achieved by combining channels, a single long trace can consume all the reference memory or zoom and math trace capacity in the instrument. When this happens, an on-screen warning message will avert accidental storing of a new trace to a reference memory already in use.

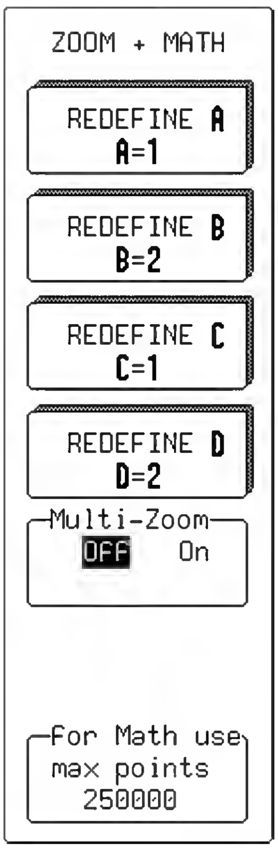
> ***Note:*** ***A processing title for each displayed trace will be shown in the Displayed Trace Label. If the title is missing, the desired processing cannot be done and the contents of the trace remain unchanged.***

Configuring for Zoom and Math

MATH SETUP

Press [MATH SETUP] to enable the configuration of any of the four traces and execute any zoom, math function using the "ZOOM + MATH" menus.

Any trace and function can be chained to another trace and function (*not all functions shown are necessarily available*). Trace A, for example, could be configured to average Channel 1, Trace B could be made a Fourier Transform (FFT) of A, and Trace C a zoom of B. All traces can be viewed simultaneously on-screen using the ZOOM + MATH TRACE ON/OFF buttons. Any function can be zoomed directly.



REDEFINE A, B, C, or D

To select the trace to be redefined and accesses the "SETUP" menus (*described in the remainder of this chapter, using A as an example)*.

Multi-Zoom

For switching Multi-Zoom "On" or "Off". When "**On**", all displayed traces (A,B,C,D) are simultaneously controlled by the horizontal POSITION and ZOOM knobs. When "**OFF**", only the active trace, chosen using the SELECT ABCD button, is controlled by POSITION and ZOOM.

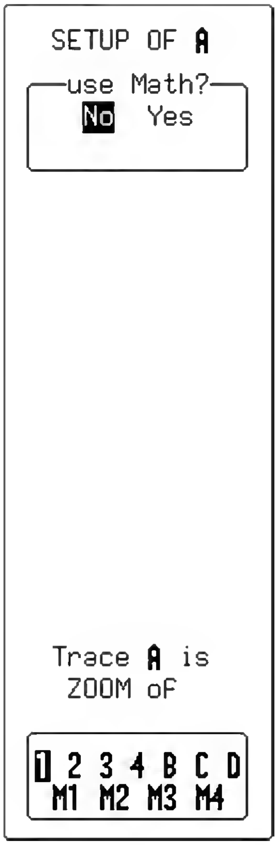
Selected (NOT SHOWN)

When a trace with a zoom of a sequence-mode waveform is selected, the "Selected" menu — not shown here — becomes accessible. Pressing the corresponding menu button toggles the selection between display of a single, specific "Segment" and "All Segments". With the former selected, the associated knob can be used to step through the segments and choose one.

for Math use max points...

For selecting the maximum number of points for all math operations — a low number increases computation speed.

Zoom



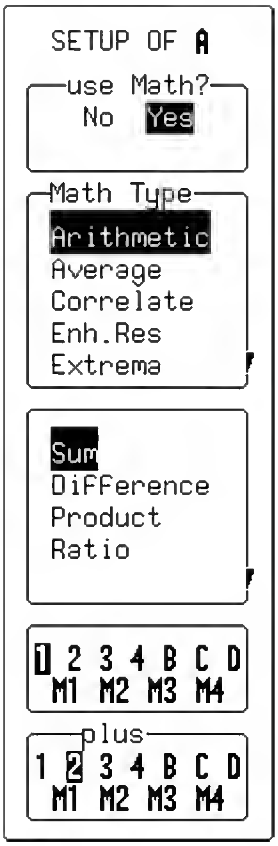
use Math?

For toggling between “**No**” (Zoom only) and “**Yes**” (Math functions) SETUP.

Trace A, B, C or D is ZOOM of

To select the source trace to be zoomed (*four-channel menu shown*).

Arithmetic — allows addition, subtraction, multiplication and division, as well as choice of the two operands and the operator. The example on this page shows a setup of trace A as the sum of Channels 1 and 2.



use Math?

To choose a math function.

Math Type

To select “**Arithmetic**”.

Sum
Difference
Product
Ratio

For selecting the operator.

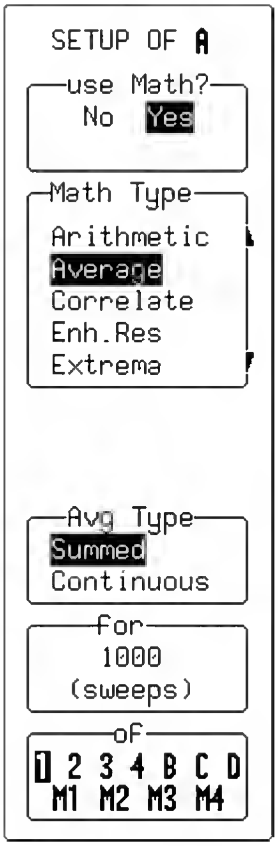
1 2 3 4 B C D
M1 M2 M3 M4

To select one of two operand source traces (*four-channel menu shown*).

plus 1 2 3 4 B C D
M1 M2 M3 M4

To select the other operand source trace (*four-channel menu shown*).

Average



— offers Summed (Linear) or Continuous (Exponential) Averaging. Shown here is an example setup of trace A as a Summed Average (over 1000 sweeps) of Channel 1. *See also page 10–2.*

use Math?

To choose a math function.

Math Type

To select, in this case, "**Average**" (*other choices in the example menu shown here include options not available on the standard scope*).

Avg Type

To select "**Summed**" or "**Continuous Average**".

for / weight

When "**Summed**" is selected, this menu ("for") is used to define the number of sweeps. When "**Continuous Average**" is chosen, the same menu becomes "weight" and is used to define the weight, similar to number of sweeps.

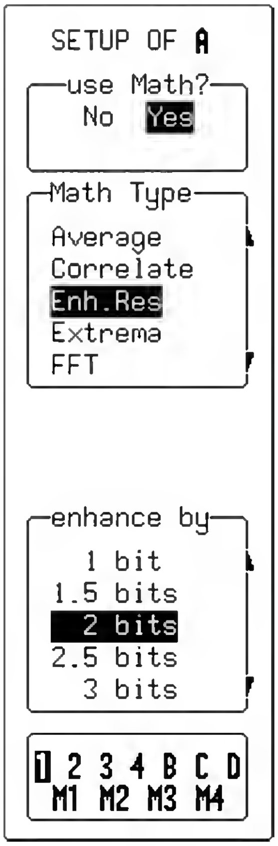
In "for" the *first* n sweeps will be taken into account, whereas in "weight" the *last* sweep will be given a weight of 1 and the previous result a weight of n in calculating the new average.

of

For selecting the source trace for averaging (*four-channel menu shown*).

Enhanced Resolution* — allows the selection of low-pass digital filters that increase the resolution of the displayed signal at the expense of its bandwidth. Appendix B gives a detailed explanation.

These digital filters work very much like analog bandwidth-limit ones. In Single-Shot mode, they and the sampling speed affect bandwidth. If high bandwidth is needed at slow timebases, averaging and repetitive sampling should be considered.



use Math?

To choose a math function.

Math Type

To select "**Enhanced Resolution**".

enhance by

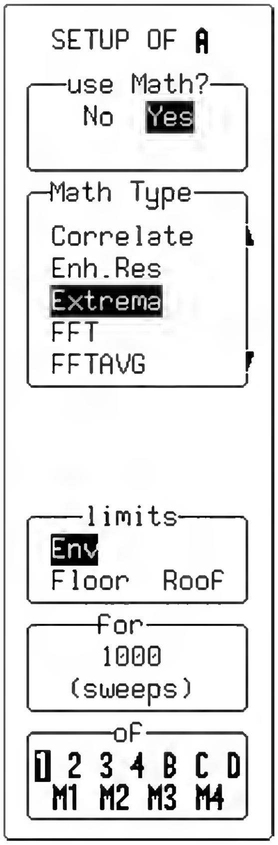
For selecting the filter that will enhance resolution of the displayed signal from one to three bits in 0.5-bit steps.

1 2 3 4 B C D
M1 M2 M3 M4

To select the source trace for filtering (*four-channel menu shown*).

* Only with WP01 Advanced Math package. *See "Signal Analysis" in Appendix A for specifications.*

SETUP Extrema† — used for acquiring a trace envelope over many acquisitions (*see also page 10–3*).



use Math?

To choose a math function.

Math Type

To select "**Extrema**".

limits

To select either "**Envelope**", "**Floor**" or "**Roof**". Floor shows only the lower, and Roof only the upper part of the envelope. Changing the limits does not force the analysis to start again.

for

For selecting the number of sweeps.

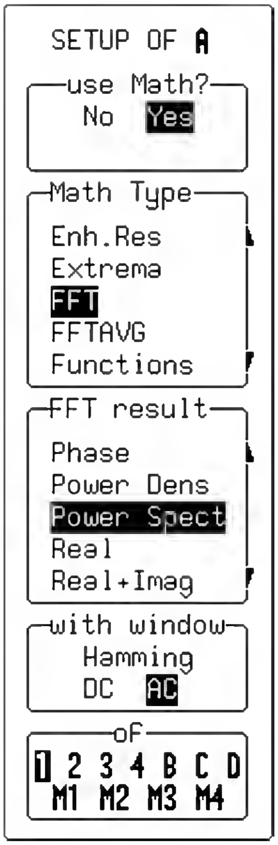
of

To select the source trace (*four-channel menu shown*).

† Only with WP01 Math package. *See "Signal Analysis" in Appendix A for specifications.*

SETUP — FFT‡

— used to display the Fast Fourier Transform (FFT) of a signal and visualize it in the frequency domain. *See the final section of this chapter, and Appendix C, for when and how to use FFT.*



use Math?

To choose a math function.

Math Type

For selecting "**FFT**".

FFT result

To select the FFT's output format: "**Imaginary**", "**Magnitude**", "**Phase**", "**Power Dens**"-ity, "**Power Spect**"-rum, "**Real**" or "**Real + Imag**".

with window

Using the corresponding menu button to select the FFT window type from "**Rectangular**", "**Hanning**", "**Hamming**", "**Blackman-Harris**", and "**Flat-top**". And the associated knob to select "**AC**" or "**DC**".

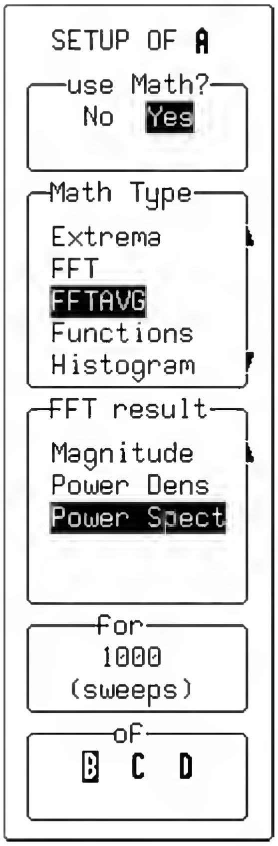
of

For selecting the source trace (*four-channel menu shown*).

> ***Note:** During Fast Fourier Transform computation the FFT sign is displayed in the lower right-hand corner of the screen. The computation of FFT on long time-domain records can take time. The computation can be interrupted or aborted at any time using any front-panel control.*

‡ Only with WP02 Spectral Analysis package. *See "Signal Analysis" in Appendix A for specifications.*

SETUP — FFT Average[§] — used for displaying the FFT power averaging of an FFT source trace, power averaging being useful for characterizing broadband noise or periodic signals without a stable trigger signal. Total power — signal and noise — is measured at each frequency. The source trace must be an FFT function. *See the final section of this chapter, and Appendix C, for when and how to use FFT.*



use Math?

To choose a math function.

Math Type

To select "**FFT AVG**".

FFT result

To select the output format of the FFT Average: "**Magnitude**", "**Power Density**", "**Power Spectrum**".

for

For selecting the number of sweeps.

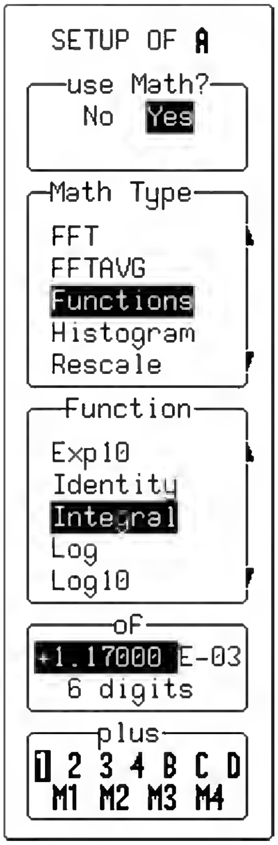
of

To select the FFT source.

> ***Note:*** ***FFT Average can be reset by pressing CLEAR SWEEPS. The number of currently accumulated waveforms is then shown in the Displayed Trace field of the function or its expansion.***

[§] Only with WP02 Spectral Analysis package. *See "Signal Analysis" in Appendix A for specifications.*

SETUP — Functions** — gives access to a menu offering a variety of Math display functions.**



use Math?

To choose a math function.

Math Type

For selecting "**Functions**".

Function

To select a function type from this list:

- "**Absolute value**"
- "**Derivative**"
- "**Exp (base e)**"
- "**Exp 10 (base 10)**"
- "**Identity**"
- "**Integral**"
- "**Log (base e)**"
- "**Log 10 (base 10)**"
- "**Negation**"
- "**Reciprocal**"
- "**Sinx/x**"
- "**Square**"
- "**Square root**"

of

For selecting the signal offset (used to compensate for any DC offset in the signal).

plus

For selecting the source trace (*four-channel menu shown*).

> ***Notes for Math Functions***
>
> - ***Square root is computed on the absolute value of the source waveform.***
> - ***For logarithmic and exponential functions the numerical value (without units) of the input waveform is used.***
> - ***For the integral function the source waveform may be offset by an Additive Constant in the range -10^{16} to $+10^{16}$ times the vertical unit of the source waveform.***

** Functions shown include functions available only with WP01 Math package. *See "Signal Analysis" in Appendix A for specifications.*

SETUP — Histogram[††] — **used to select the histogramming function and set-up for parameter analysis.**

use Math?

To choose a math function.

Math Type

For selecting "**Histogram**".

MORE HIST SETUP

To access the secondary menu offering more histogram settings.

FIND CENTER AND WIDTH

To calculate optimal center- and bin-width values for the histogram.

Histogram

To select up to five source parameters for histogramming.

using up to

For limiting the total histogram population.

[††]Only with WP03 Parameter Analysis or DDM/PRML Disk Drive Measurements/Supplementary Disk Drive Measurements packages. *See these options' respective Operator's Manuals.*

SETUP — Rescale

— for selecting a waveform and adjusting a, the multiplication factor, and b, the additive constant, in:

$$(a * \text{waveform}) + b,$$

where both constants can have values ranging between -10^{15} and $+10^{15}$.

use Math?

To choose a math function.

Math Type

For selecting "**Rescale**".

(a * 1) + b

To select "**a**" or "**b**".

a = or **b =**

The corresponding menu button for this menu highlights the mantissa, the exponent, or the number of digits, while the associated knob changes the highlighted value.

1 2 3 4 B C D
M1 M2 M3 M4

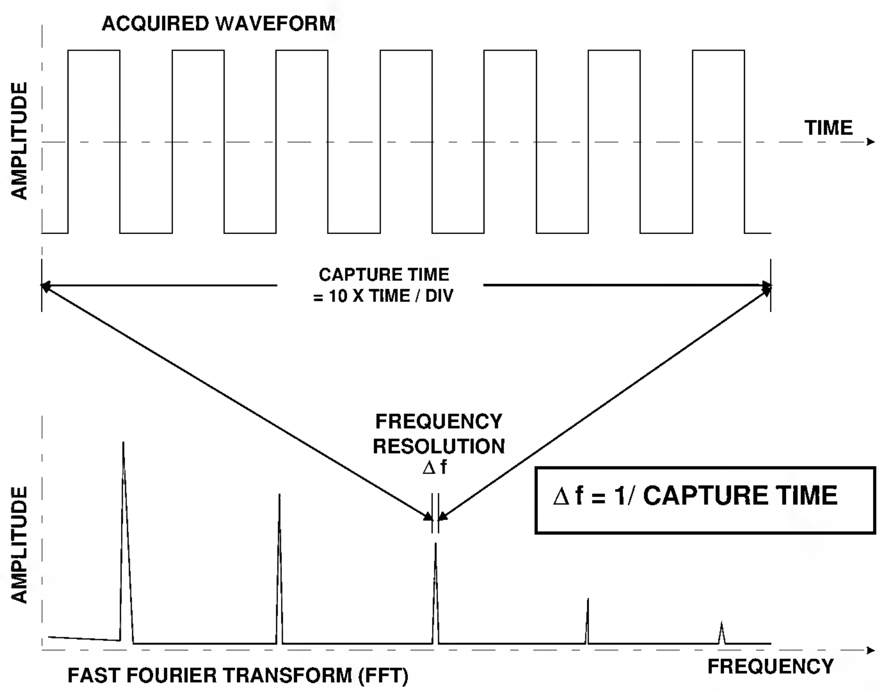
To select the source trace (*four-channel menu shown*).

Setting Up FFT Span and Resolution

The FFT (Fast Fourier Transform) converts a time domain waveform into frequency domain spectra similar to those of an RF spectrum analyzer display. But unlike the analyzer, which has controls for span and resolution bandwidth, FFT span is determined by sampling rate, while resolution bandwidth is inversely proportional to record length.

Frequency Resolution Δf

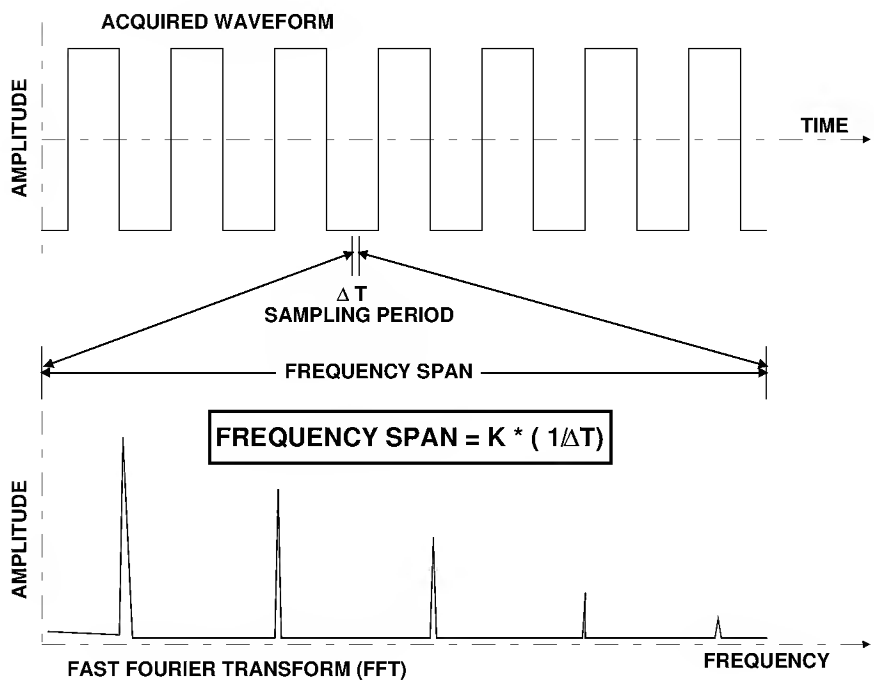
Correctly setting up an FFT starts with the frequency resolution, or Δf. This parameter is the spacing of samples in the frequency domain display. The Δf is set by inputting the time duration of the time domain signal to the FFT. If an acquisition channel (Channel 1 or 2, or 3 or 4) is the source, then the waveform duration is the capture time: the TIME/DIV setting multiplied by ten. *The relationship between capture time and frequency resolution is illustrated here.*



Similarly, if the source waveform is a zoom trace, the frequency resolution is the reciprocal of the displayed waveform's duration.

Setting the Span

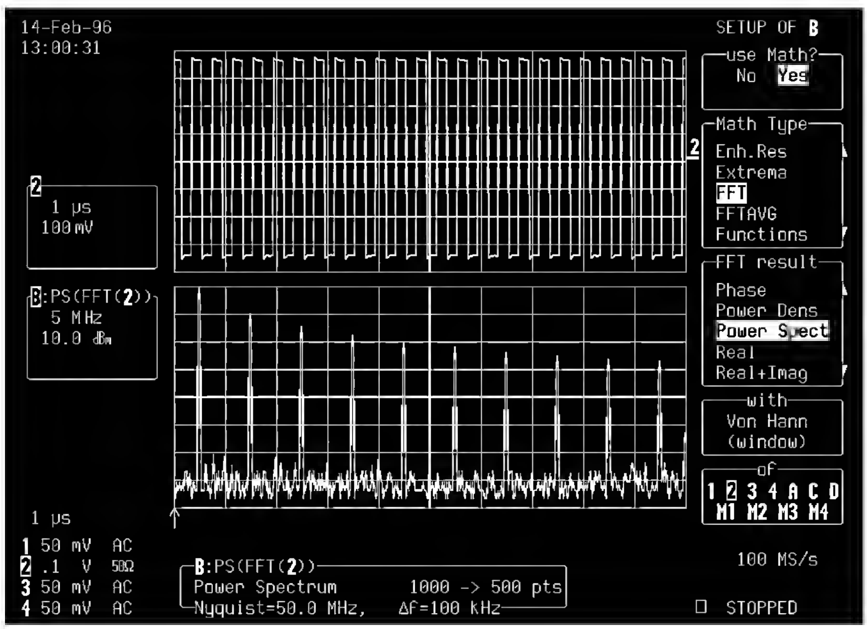
The frequency span of the FFT is called the Nyquist frequency and is related to the sampling frequency of the time domain waveform. If the math memory size, set using the "for Math use max points" menu (*see page 10–6*), is identical to the number of samples in the acquired waveform ("TIMEBASE" menus, *Chapter 7*), then the span will be half the sampling frequency. But if this "max points for math" number is less than the number of points, the waveform and in turn the FFT span will be decimated. *The relationship between the span of the FFT and the sampling rate (1/ΔT) is illustrated here.*



The constant K in the illustration includes the decimation factor described above, as well as automatic display scaling factors. This scaling is required to ensure that the FFT's horizontal display scale falls into a 1,2, or 5 factor.

In essence, the oscilloscope automatically adjusts the span (and hence the FFT transform size) to account for the user-entered "max points for math" and the display scaling. In some combinations of these factors it also adjusts the length of the displayed trace.

The user can determine the span from the Displayed Trace Label for the math trace containing the FFT. This will show the horizontal calibration in MHz/div. The span is also explicitly shown as the Nyquist frequency in the information field that appears at the bottom of the screen when the "MATH SETUP" menus are displayed, *as shown here.*



Essentially...

To achieve a desired FFT span, first make sure that the sampling rate is more than twice the span desired. Control the sampling rate using the TIME/DIV knob and set the acquisition memory length with the "TIMEBASE" menu. The sampling rate can be further adjusted by limiting the number of points in the "for Math use max points" menu.

Example

Set up the oscilloscope for an FFT with a span of 10 MHz and a frequency resolution of 10 kHz, to analyze a continuous, periodic waveform.

1. The required frequency resolution demands a waveform duration (capture time) of 100 µs. Setting the TIME/DIV to 10 µs achieves the necessary Δf of 10 kHz.
2. To obtain the specified 10 MHz span, the effective sampling rate must be > 20 MS/s. On, say, an oscilloscope with a sampling rate of 500 MS/s, the 50 000-sample default memory length and a 10 µs TIME/DIV setting would be used to first give a 250 MHz span. Now, to obtain a 10 MHz span, the sampling rate must be reduced. This can be done in either of two ways:
   a) In "TIMEBASE": decreasing the number of samples by setting the "RECORD UP TO" menu to 2500 results in a sampling rate of 25 MS/s.
   b) With "ZOOM + MATH", by setting the "for Math use max points" menu to 2500. This would leave the sampling rate at 500 MS/s but decimate the waveform data before the FFT by 20 000:1, thus reducing the effective sampling rate to 25 MS/s. This would in turn result in a span of 12.5 MHz, the closest achievable span to > 10 MHz.

Note: ***The technique described in b) above is to be preferred because it maintains a high input sampling rate and reduces the risk of aliasing the acquired data.***

This example, *illustrated below*, shows how the oscilloscope maintains the display factor. A sampling rate of 25 MS/s would result in a full scale range of 12.5 MHz or 1.25 MHz/Div. To maintain a display scale factor of 1,2, or 5 it decimates the acquired waveform by 25 000:1 and calculates the FFT using a 2000-point transform. This results in a scale factor of 2 MHz/Div. The display is truncated at 6.25 divisions to retain the original 12.5 MHz span.